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(71) Applicants:
- Goldsworthy, William Brandt
Torrance, California 90505 (US)
- Korzeniowski, George
Torrance, California 90505 (US)

(72) Inventors:
- Goldsworthy, William Brandt
Torrance, California 90505 (US)
- Korzeniowski, George
Torrance, California 90505 (US)

(74) Representative:
LOUIS, PÖHLAU, LOHRENTZ & SEGETH
Postfach 3055
90014 Nürnberg (DE)

(54) Composite reinforced electrical transmission conductor

(57) A composite reinforced electrical transmission conductor primarily designed for transmission of electrical signals in the nature of telephone signals. The conductor is comprised of a reinforced plastic composite inner core along with an outer highly electrically conductive sheath therearound. In this way, the inner core provides the necessary strength and the outer sheath provides for transmission of the electrical signals. In a preferred embodiment, the reinforced composite core is comprised of individual sections which cooperate together to provide the necessary loading capabilities. Further, a fiber optic cable may also be carried by the composite reinforced core. A splicing arrangement for securing ends of the cable together is also provided.

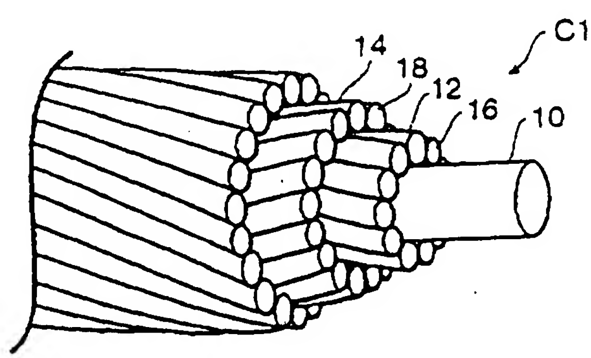

FIG. 1

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Description

BACKGROUND OF THE INVENTION

[0001] This invention relates in general to certain new and useful improvements in electrical transmission cables and, more particularly, to electrical transmission cables which have a composite reinforced component to provide load carrying capabilities.

[0002] Electrical conductor technology has, in the relatively recent past, moved to the exploratory use of composite cores, such as carbon, ceramics and fiberglass. These materials offer unprecedented technical performance advantages over the earlier electrically conductive materials. It is desirable to provide a composite reinforced aluminum conductor for replacement of the heavy steel strength member of the aluminum core steel reiforced (ACSR) with a high strength and lower weight glass-fiber composite material. The current carrying component is still pure aluminum. The main difference between the ACSR and the composite reinforced aluminum conductor ("CRAC") is that the CRAC will have a higher percentage by volume of a conductive component. This improvement is actually made possible by the much greater tensile strength of a composite, such as glass resin, relative to the steel and this frees up space in the conductor's volume for more aluminum. This further significantly increases conductor current carrying capacity along with significantly lower weight.

[0003] It can be seen from the above that some of the specific advantages of the CRAC is that:

1. The cost of the composite reinforced conductor is equal to or less than the cost of the traditional steel cable conductor of the same diameter.
2. The composite materials used as the center core have a coefficient of thermal expansion which is fifty percent less than the steel core reinforcement.
3. The tensile strength (breaking strength) is about one hundred fifty percent higher than carbon steel core wire (with HC steel being approximately 210ksi).
4. Conductivity of composite reinforced conductors is at least forty percent higher and having a target value of as much as two hundred percent higher than ACSR conductors of the same outer diameter.
5. The CRAC conductors are also capable of utilizing T&D accessories and other accessories which are installed in a similar manner in traditional cable.
6. The CRAC cables have the capability of being used with field installation equipment and procedures which exist with minimum modifications.
7. The composite materials are compatible with conventional wire and cable process technology.
8. The CRAC cables eliminate eddy-current heating.
9. A solid aluminum core has 1/100 degree of radial temperature differences as compared to stranded wire.
10. There is no loss of strength in a CRAC and consequent increase in sag due to annealing of the tension member.
11. The CRAC has simplified manufacturing requirements because there is no need for multiple layers of stranded aluminum in order to cancel out self-inductance.
12. There is an elimination of non-uniform current flow due to self-inductance when using the CRAC.

BRIEF SUMMARY OF THE INVENTION

[0004] The present invention relates in general to electrical current carrying conductors which utilize an inner load bearing core formed of a reinforced plastic composite material in place of the conventional steel core.

[0005] The current carrying cable of the present invention in outer appearance is very similar to the conventional electrical current carrying cable having the inner steel core. In addition, and in one of the important aspects of the invention, the cable of the present invention can be used in precisely those locations in which conventional cables are presently used and they can be mounted in precisely the same manner. Thus, substitution of a cable of the type provided in accordance with the present invention can be accomplished easily and at low cost and, more importantly, with existing cable laying equipment.

[0006] The current carrying conductor of the present invention includes the reinforced plastic composite core, as aforesaid. Preferably, this core is formed of individual segments which are fitted together to operate as a single composite fiber reinforced core. The individual segments are somewhat trapezoidal shaped with the outer surfaces thereof being arcuate. In this way, the trapezoidal shaped pieces as, for example, six individual pieces or segments of the core, are arranged in a cylindrical format so that the core actually is cylindrical when assembled.

[0007] The inner core is formed of a plurality of fibers or strands of reinforcing material, such as fiberglass, boron, carbon or the like, and which are held together by a binding agent, such as a thermoplastic or thermosetting resin. Thermoplastic material is preferred due to the fact that it can be easily heated and bonded on a job site and also the heating and bonding occurs much more quickly with a thermoplastic material than with a thermosetting material.

[0008] It has also been found that it is possible to literally use as smelted aluminum for higher current carrying conductivity capabilities.

[0009] The present invention also provides a proposed method and system for splicing the ends of the individual cables. As indicated previously, the cables can only be carried to a job site in finite lengths. Consequently, the splicing of cable lengths is necessary for long distance transmission.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Having thus described the invention in general terms, reference will now be made to the accompanying drawings in which:

Figure 1 is a fragmentary perspective view of a composite reinforced current carrying conductor constructed in accordance with and embodying the present invention;

Figure 2 is a fragmentary perspective view, similar to Figure 1, and showing a slightly modified form of composite reinforced current carrying conductor in accordance with the present invention;

Figure 3 is a fragmentary perspective view showing still a further modified form of composite reinforced current carrying conductor in accordance with the present invention;

Figure 4 is a fragmentary perspective view of yet another modified form of composite reinforced current carrying conductor in accordance with the present invention and containing the fiber optic cable;

Figure 5 is a fragmentary perspective view, similar to Figure 4, and showing portions of the core spread apart to accept a fiber optic cable;

Figure 6 is a fragmentary perspective view showing one form of apparatus for producing a composite reinforced current carrying conductor in accordance with the present invention;

Figure 7 is an exploded perspective view showing one method of splicing ends of the current carrying conductor of the present invention;

Figure 8 is a side elevational view showing the technique in the splicing of the cables of Figure 7; and

Figure 9 is a composite of Figure 9a, 9b and 9c showing a finished splice and method providing a fiber optic cable to be spliced at a ground level.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0011] Referring now in more detail and by reference characters to the drawings, which illustrate preferred embodiments of the present invention, C_1 illustrates an electrical transmission cable having a reinforced plastic composite load bearing core 10 and a plurality of outer layers of aluminum wire 12 and 14 extending thereabout.

[0012] By further reference to Figure 1, it can be seen that the load bearing core 10 is a solid reinforced plastic composite member. Also, in the embodiment as illustrated in Figure 1 and the subsequently illustrated and described embodiments, there are three outer aluminum layers 12, 18 and 14 (see Figure 1), although it should be understood that any number of outer layers could be employed depending upon the desired thickness of the outer current conducting sheath to be formed over the core. It can be observed that in this construction, the cable C_1 is similar in appearance to a conventional steel core cable. Consequently, it can be laid in the same fashion or suspended in the same fashion and using the same equipment as that employed for a steel core cable.

[0013] In a preferred embodiment, the strands are formed of any suitable reinforcing fiber, such as glass, boron, carbon or the like. Moreover, the resin matrix which is used to bind the strands may be formed of any suitable thermoplastic resin or thermosetting resin. Some of the thermosetting resins which may be used include, for example, various phenolics and epoxies and many polyesters which are conventionally known for that purpose. However, the thermoplastic resins are preferred and include, for example, polypropylene, polycarbonates, etc.

[0014] It is preferred to use individual ropes or strands of thermoplastic resin along with the individual strands of the fiber reinforcing strands. Thus, the resin strands can be commingled with the fiber strands and they can be applied as a bundle. Otherwise, the resin strands can be applied individually with the fiber strands. Upon heating, the resin will then soften and liquefy and flow around the individual fiber containing strands. When the resin is allowed to harden, an inner core will therefore be formed.

[0015] It should also be understood in connection with the present invention that aluminum is only one form of current carrying conductor which could be employed as the outer skin. Thus, copper or other high current conductivity materials could be used for this purpose.

[0016] The composite core can be formed in any of a variety of ways. For example, the composite core could be extruded, as such. However, preferably, the reinforced composite when formed as a rod in the embodiment as shown, would preferably be pultruded. Several processes for this pultrusion operation are described in numerous U.S. patents as, for example, U.S. Patent No. 3,650,864 to William Brandt Goldsworthy, U.S. Patent No. 3,576,705 to William Brandt Goldsworthy, U.S. Patent No. 3,769,127 to William Brandt Goldsworthy, and U.S. Patent No. 3,579,402 to William Brandt Goldsworthy, et al.

[0017] The embodiment of Figure 1 is primarily effective for only short length cables. This is due to the fact that the reinforced plastic core 10 is not capable of significant bending movement. It may be appreciated that the entire cable must be capable of being wound about a drum and transported for a substantial distance where it would then be unwound from the drum and either suspended or laid at a site of use. For this purpose, the central core 10 is preferably formed of a plurality of individually shaped core sections 20, as best shown in the cable C_2 of Figure 2. In this particular case, the individual sections 20, when assembled together, create a cylindrically shaped cable 22.

[0018] In the embodiment of the invention as shown in Figure 2, six individual pie-shaped sections are pro-

vided. However, any number of sections could be provided. In connection with the present invention, it has been found that the five individual sections are preferred inasmuch as this is the number of sections which allow for a bending of the cable and a winding of the cable about a spool.

[0019] The cable C_2, as shown in the embodiment of Figure 2, is also wrapped with layers of electrically conductive material as, for example, individual strands of aluminum wire 24 and 26 which form the two outer electrically conductive layers. Again, any desired number of layers could be used. Furthermore, in the embodiment of Figure 2, the individual strands 24 and 26 are helically wound about the central load bearing core 22.

[0020] In connection with the following described embodiments, like reference numerals will represent like components. Figure 3 illustrates an embodiment of a cable C_3 forming part of the present invention also having a segmented central core 22 and a pair of electrically conductive outer layers 30 and 32 wrapped about the central core.

[0021] Figure 4 illustrates an embodiment of a cable C_4 similar to the cable C_3, except that in this particular case, the individual pie-shaped sections 20 of the core 22 are formed with an arcuately shaped recess 34 formed at their inner most ends. In this particular embodiment, the inner most ends 34, as shown in Figures 4 and 5, form a cylindrically shaped central, axially extending bore 36 which are sized to receive a fiber optic cable 38.

[0022] This embodiment of a cable C_4 is highly effective in that it not only provides for substantial current carrying capacity, but it also allows for the carrying of a fiber optic cable in such manner that the cable is not subjected to environmental degradation or the constant repair required for such cable.

[0023] With presently employed fiber optic cable for transmitting fiber optic messages over long distance, a complex scheme is required for splicing ends of the fiber optic cable and, for that matter, even repairing the cable. Typically, the cable must be lowered to a repair station or otherwise a splicing station located approximately at ground level. Moreover, with a conventional steel core electrical transmission cable, there is no effective way to form a central opening extending axially through the core and no effective way to even thread a fiber optic cable through an opening in the core. As a result, and as indicated previously, fiber optic cable is wrapped about the outer surface of the guard wire. The present invention overcomes this problem completely, in that the fiber optic cable can be literally enclosed in the electrical transmission cable as the latter is being formed.

[0024] By reference to Figure 6 of the drawings, it can be observed that each of the individual sections 20 may be pre-formed in an extrusion operation, or otherwise a pultrusion operation, as previously described. These individual sections, when hardened, are then threaded through a die plate or carding plate 40 having individual tubes 42 with essentially the same shape as the individual core sections 20, but sized to receive these core sections 20.

[0025] Figures 7 and 8 illustrate a preferred embodiment for splicing the ends of the electrical transmission cable in accordance with the present invention. In this particular case, and in order to splice the ends together, the individual cable sections 20 are each spliced with staggered ends, as best shown in Figure 7. Thus, one of the individual sections 20_a on one fiber optic cable 50 has a length which is longer than any other section of that cable 50. That particular core section 20_a will match and mate with the shortest cable section 20_b on an opposite cable 52 to be spliced. In this manner, a shorter cable section 20_c on the cable 50 will match and mate with a cable section 20_d in the cable 52. In this way, each staggered length will mate with a corresponding staggered length of the opposite cable. Moreover, the individual cable sections will then fit together much in the manner as pieces of a puzzle fit together.

[0026] After the individual staggered sections have been brought together, they can be heated slightly to cause the thermoplastic resin or other resin to liquefy and flow between the staggered ends to thereby bind the staggered ends together.

[0027] Thereafter, the outer aluminum layers can then be coupled to one another in the same manner as they are presently coupled with steel core cables. Typically, the outer electrically conductive layers of one cable 50 are connected to the outer electrically conductive layers of the cable 52 by use of electrically conductive sleeves which are secured thereto and extend over the joined ends, as best seen in Figure 9.

[0028] In accordance with standard cable splicing techniques, and particularly for fiber optic cable, the cable is brought to a ground level for connecting the ends of fiber optic cable sections. The technique for this arrangement is shown in the composite of Figures 9a through 9c. The two cable sections 50 and 52 when the splicing is completed are covered with an outer sheath 60, as shown in Figure 9a. By reference to Figure 9b, which is a cross-section of Figure 9a, it can be seen that after the ends of the two cable sections 50 and 52 are spliced, the outer aluminum conductors 64 and 66 respectively on these cable sections are then brought together when the aluminum sleeve 60 is disposed thereover. Prior to actually installing the sheath, the fiber optic cables are brought to a ground level for purposes of splicing same. It can be seen by reference to Figure 9c that the cable sections are actually extended down toward a ground level for splicing at a splicing station and thereafter raised and located in the region of the sleeve 60 much in the manner as shown in Figure 9c.

[0029] The electrical transmission cables of the invention also are adapted to carry more electrical current then a comparably sized steel core conductor. This is due to the fact that more of the highly conductive metal, such as aluminum, is capable of being carried with a

reinforced plastic core then would be carried with a similarly sized steel cable with no weight increase and some weight decrease. As a result, support towers do not need to be rebuilt to accommodate heavier equivalent capacity conductors.

[0030] It has been found that the cables of the present invention will actually carry five percent more electrical current compared to a steel reinforced aluminum conductor. In addition, there is a reduced mechanical elongation or line sag at high operating temperatures. Further, it has actually been established that the cables of the invention are two hundred fifty percent stronger then the steel reinforced aluminum conductor of essentially the same size and, moreover, is seventy-five percent lighter than steel reinforced aluminum conductors.

Claims

1. An improved electrical current carrying conductor for long distance transmission of electrical current and having a central load carrying conductor and an outer sheath therearound, the improvement in said current carrying conductor further characterized in that:

   a) the load carrying core being formed of a fiber containing reinforced composite material; and
   b) the outer highly conductive electrical current carrying sheath completely surrounding said load carrying core.

2. The improved electrical current carrying conductor of Claim 1 further characterized in that said reinforced composite material is comprised of a plurality of aligned reinforcing fibers embedded in a thermoplastic composite matrix.

3. The improved electrical current carrying conductor of Claim 1 further characterized in that said central load carrying core is comprised of a plurality of individual sections which are capable of being separated from one another for purposes of splicing.

4. The improved electrical current carrying conductor of Claim 3 further characterized in that said individual sections are concentrically arranged to form a cylindrically shaped conductor and that said individual sections are somewhat trapezoidal shaped and form a central bore sized to receive a fiber optic cable.

5. An improved method for producing a long distance transmission current carrying conductor of Claim 1 wherein the improved method is characterized in the steps of:

   a) bringing a plurality of individual reinforced plastic composite sections together to form a generally cylindrically shaped conductor core; and
   b) locating on an outer cylindrically shaped surface of said core an outer highly conductive electrical current carrying conductor.

6. The improved method for producing a long distance transmission current carrying conductor of Claim 5 further characterized in that said step of locating the current carrying conductor comprises winding strands of a highly conductive current carrying conductor about said central core.

7. The improved method for producing a long distance transmission current carrying conductor of Claim 5 further characterized in that said method comprises the bringing of the composite sections together about a fiber optic cable so that the current carrying conductor also includes a fiber optic cable therein.

8. A method for splicing ends of improved first and second current carrying cables of Claim 5 comprised of a fiber containing reinforced plastic composite core and an outer highly conductive current carrying sheath, said method comprising:

   a) cutting the ends of the individual sections of a first cable to be spliced at staggered lengths relative to one another so that each section of the central core of that cable has a length different from the length of any other section of that first cable;
   b) cutting the ends of the individual sections of a second cable to be spliced at staggered lengths relative to one another so that each section of the central core of that second cable has a length different from the length of any other section of that second cable;
   c) matching the ends of the first cable sections with corresponding ends of the second cable so that the ends of the first cable sections will abut against corresponding ends of the second cable sections when all of the individual sections are abutted;
   d) heating spliced ends of the individual cable sections as abutted to cause a resin impregnated in the cables to partially liquefy and effectively flow around corresponding ends; and
   e) allowing the resin to cool thereby permanently bonding the core sections of the first cable to the core sections of the second cable.

9. The method of splicing cables of Claim 8 further characterized in that said method comprises matching the shortest length of a cable section of the first cable with the longest length cable section of the second cable and correspondingly matching the

longest length section of the first cable with the correspondingly shortest length section of the second cable.

10. The method of splicing cables of Claim 9 further characterized in that said method comprises securing the ends of an electrically conductive current carrying sheath on said first and second cables together in order to permit electrical conductivity through the sheaths of said cables.

11. The method of splicing cables of Claim 8 further characterized in that said method also comprises splicing the ends of fiber optic cables carried in the core of each of the individual first and second cables.

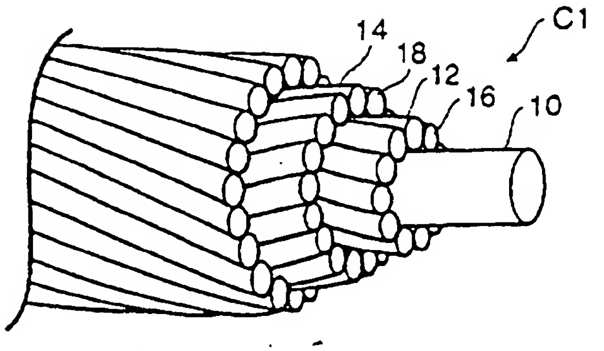

FIG. 1

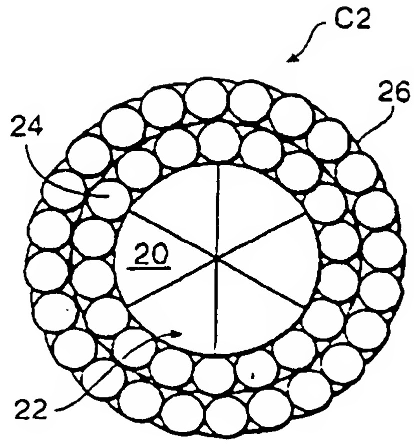

FIG. 2

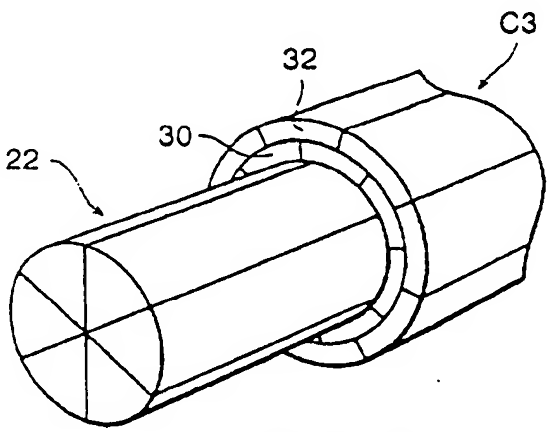

FIG. 3

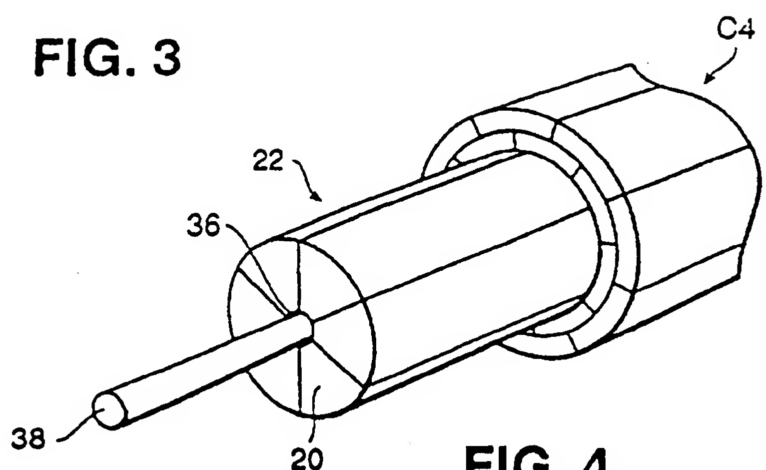

FIG. 4

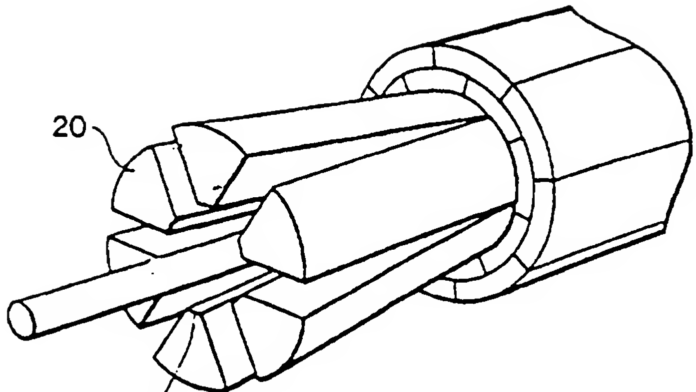

FIG. 5

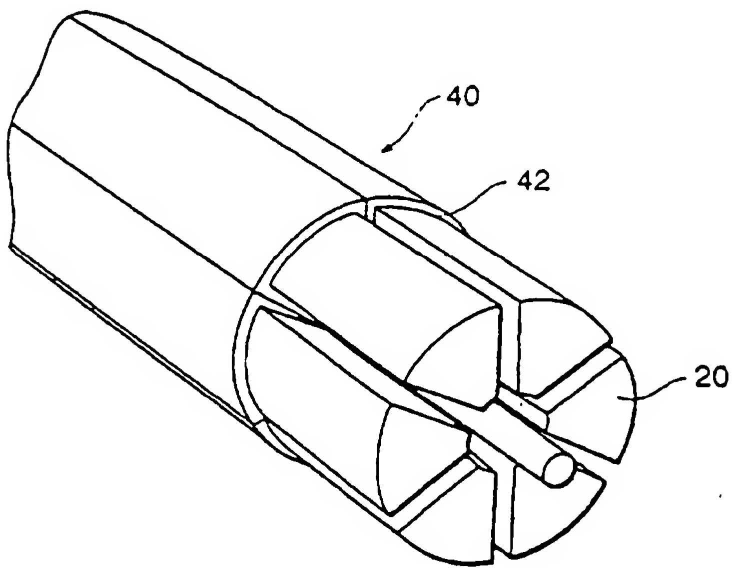

FIG. 6

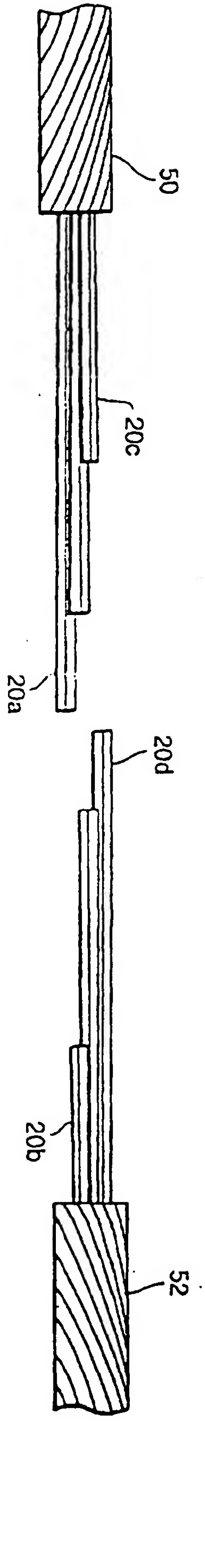

FIG. 8

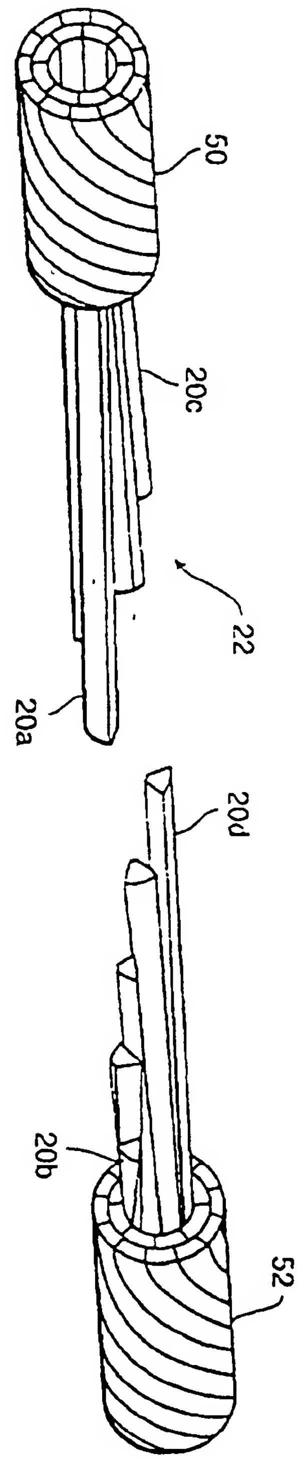

FIG. 7

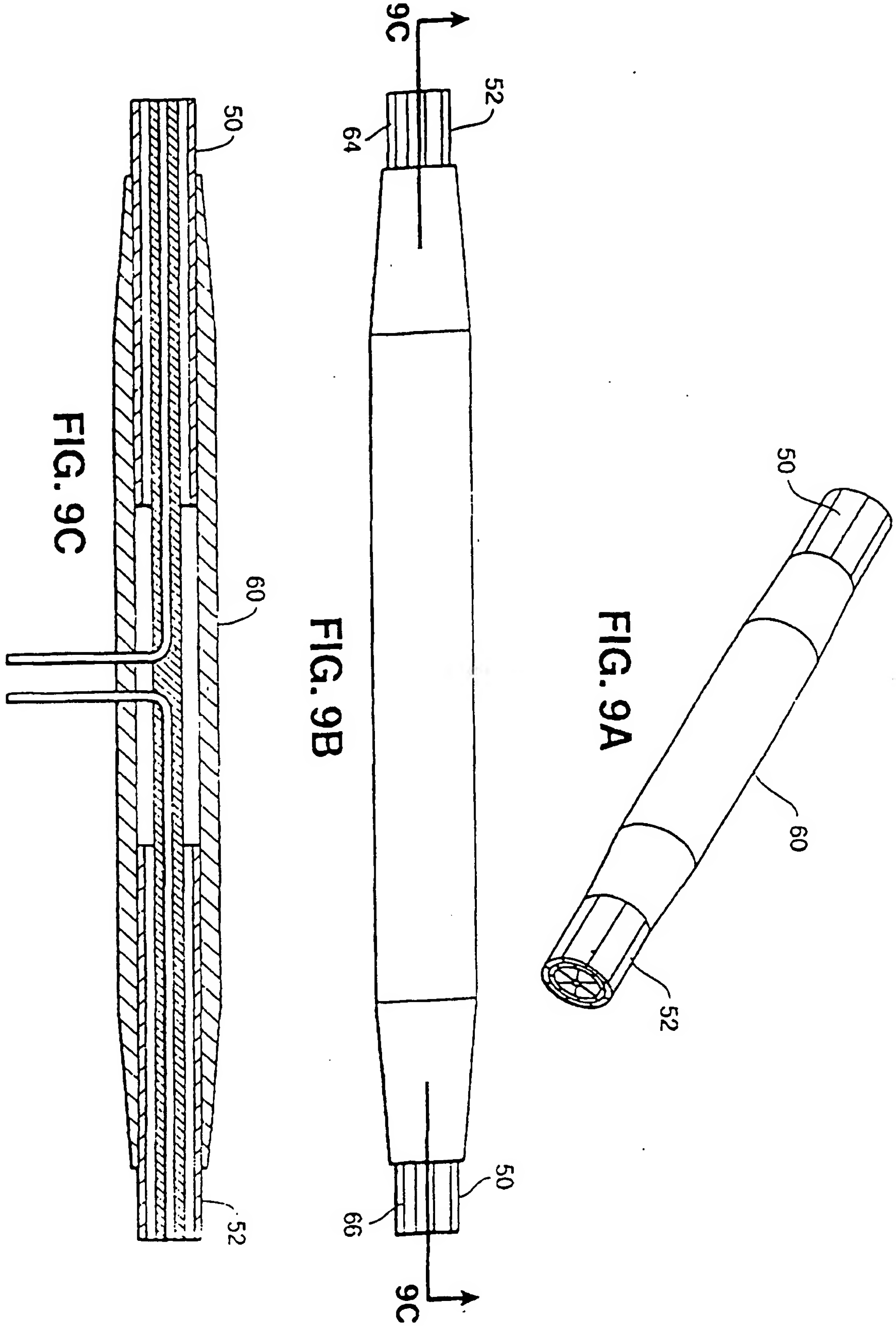

FIG. 9A

FIG. 9B

FIG. 9C